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BELLCOMM, INC.
955 L'ENFANT PLAZA NORTH, S.W. WASHINGTON, D. C. 20024

SUBJECT: Comparison of Apollo/Saturn V Hold and Scrub-Turnaround Capabilities Between C' and the F&G Missions Case 320

DATE: January 23, 1969

FROM: C. H. Eley III

ABSTRACT

The ability of F and G vehicles to meet successive launch windows by hold or turnaround operations following a scrub will be somewhat less than that of the C; vehicle (AS-503) due to the configuration difference (LM) and mission requirements.

A brief summary of the discussion:

a. Assuming a "hybrid" (i.e. partial) vehicle turnaround, an F or G launch can be slipped one day following a scrub at or prior to T-8 hours.

b. A one-day launch slip after LV cryo load or from any T-time after T-8 hours (as was possible with C') for F or G is presently constrained by (1) LM-SHe reservicing requirements, and (2) Flight crew turnaround.

c. Assuming a complete F or G vehicle turnaround is required, the launch will slip:

1. A minimum of three days following a scrub after T-9 hours.

2. A minimum of two days following a scrub at or prior to T-9 hours

3. A minimum of one day following a scrub at or prior to 22 hours.

(NASA-CR-106421) COMPARISON OF APOLLO/SATURN 5 HOLD AND SCRUB-TURNAROUND CAPABILITIES BETWEEN C AND THE F AND G MISSIONS (Bellcomm, Inc.) 22 p

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FF No. 602(A) (PAGES) (CODE)
CR-106421
(NASA CR OR TMX OR AD NUMBER) (CATEGORY)

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MEMORANDUM FOR FILE

I. INTRODUCTION

The time required to turnaround and launch an Apollo/Saturn V following a scrub has been of considerable interest in formulating lunar mission planning.* The limited number of landing sites has focused attention on reducing scrub-turnaround requirements to have a capability of meeting all launch windows in a monthly opportunity. Efforts to achieve this are continuing through inter-Center coordination; however, a lack of experience coupled with spacecraft servicing constraints has hampered efforts to reduce "worst-case" requirements to any great degree. This paper summarizes current Apollo/Saturn scrub-turnaround capabilities with regard to the F and G missions including differences from the C' mission.

II. BASIC REQUIREMENTS

The essential characteristics of scrub-turnaround operations are:

a. Vehicle operations are basically performed in three separate phases: (1) backout, (2) reservice/reverification, and (3) launch countdown.

Table I compares nominal SV turnaround times for the C', F and G vehicles from scrubs at various T-times. It can be seen that C' turnaround times were slightly higher than those for F and G even though C' did not carry a LM. The greater turnaround times for C' stemmed from serial time required to reservice the Film Camera System (FCS) located in the forward section of the S-IC.** However, the FCS is a configuration item not carried on F and G vehicles, and therefore is not a consideration.

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*Turnaround encompasses those operations formerly known as "recycle and countdown." A "scrub" is defined here as suspension of attempt to meet a given launch window.

**Refurbishment of the FCS was not a mandatory requirement for C'. Hence, a reduction in the total turnaround time was possible if it had been decided to waive refurbishment.

TABLE I

COMPARISON OF TURNAROUND TIMES, C' VS F&G*

COUNTDOWN EVENT	T-TIME	TURNAROUND TIME - HRS.	
		C' MISSION	F&G MISSIONS
F-1 ENGINE IGN. CMD.	T-8.9 SEC.	67.5	65.0
FLIGHT CREW INGRESS	T-2:40	66.5	64.0
START LV LH_2 LOAD	T-5:00	66.0	63.5
START LV LOX LOAD	T-8:00	61.3	59.0
JACK MSS	T-10:45	58.0	55.5
LM-SHe TOPOFF	T-17:00	----	53.0
CSM CRYO GSE DISCONN.	T-27:30	39.5	39.5

*Complete vehicle turnaround operations

Factors in addition to turnaround operations which must be considered are:

1. cause of the scrub
2. repair requirements
3. flight crews
4. time to next available launch window(s).

It is highly probable that a scrub will not be declared at the first indication of a malfunction during the countdown, but that every effort will be made to meet the scheduled launch window. A scrub, therefore, can generally be expected to occur late in the countdown where the turnaround requirements are greater. Repair requirements may also impact turnaround operations by introducing serial time. The total turnaround time (nominal operations plus any serial time), then, must be compared with the time to the next available launch window(s) in determining when the launch can occur.

III. LAUNCH ABILITY

A. Mission Characteristics vs. Turnaround

One basic difference between C' and the F or G mission is the spacing of launch windows in a lunar launch opportunity. F and G vehicles will launch on specific days keyed to selected landing sites; whereas, C' launch windows occurred on consecutive days. Also, there are fewer windows available for F or G than were available for C' (four vs seven).* The additional launch windows and the one-day space between each gave C' a greater launch flexibility because more scrub-turnaround options were available.

A second difference between C' and the F or G mission is vehicle hold capability. While a "scrub" connotes an "automatic" turnaround, this may not necessarily be required. The ability to hold the space vehicle for extended periods late in the countdown can greatly influence launch slippage following a scrub. The hold capability of F and G vehicles as compared with C' is dependent on the following factors:

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*The actual number of launch windows for the F mission may increase. However, four windows are used here since "fidelity" between the F and G missions has been stressed as a criterion.

a. Vehicle Configuration

C' did not carry a LM as will F and G vehicles; also, F and G-1 vehicles will not carry an ALSEP-RTG unit.

b. Mission Duration

The F mission will be slightly longer than C', while the G mission will be slightly longer than F.

c. T-time of Hold

The maximum allowable hold capability is determined by the usage limits of on-board consumables, which in turn are controlled by (a) and (b) above.* Since on-board consumables are initially loaded at specific T-times as the countdown progresses, the T-time of hold is a controlling factor determining the maximum hold capability. Figure 1 shows the maximum vehicle hold capability at any T-time for the C', F and G vehicles.

B. C' Mission - Launch Following a "Complete" Turnaround

The following C' scrub-turnaround capabilities are for a complete vehicle turnaround; that is, operations to reservice both the spacecraft and launch vehicle. A "complete" vehicle turnaround curve for C' is shown in Figure 2. By subtracting the unused time (T-time of scrub) from the turnaround time, a "minimum" launch slippage curve is obtained--shown as a dotted line in Figure 2. Figure 3 shows the "minimum" C' launch slippage for a scrub at any T-time against the relative launch window positions in the December 1968, launch opportunity. For instance, for a scrub after T-9 hours, the C' launch would have slipped at least three days if CSM cryo reservicing were necessary.

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*The ALSEP-RTG is not a consumable. However, it does generate great quantities of heat which could impose a hazard in the case of extremely long holds (a day or more). This is not considered a problem since the unit can easily be removed; however, this would mean holding at a different T-time.

1. Hybrid Turnaround, C' Mission

A short or "hybrid" type of turnaround was possible for C' depending on the cause of scrub and T-time of occurrence.* For instance, if a scrub had occurred prior to LV cryogenics loading, the C' launch could have been slipped one day provided the CSM cryos did not have to be reserviced. KSC also stated a capability to meet a one-day slip from a point after LV cryo loading provided (1) the MSS was not returned to the pad, (2) the conoseal leak check and torquing could be waived,** and (3) the main LOX tank at Pad A could be replenished to approximately 750,000 gallons. This would have been, in fact, essentially a "holding" operation which will not be possible for F or G vehicles after T-17 hours unless the LM-SHe is reserviced (Reference 8).

C. F and G Mission Launch Ability

There are only five possible turnaround cases for F or G missions (graphically shown in Figure 5). The number of cases is limited by (a) the number of landing sites, and (b) their selenographical position. The five turnaround cases are:

Case	Change in Landing Site	Time Available (days)***
#1	IIP-2 to IIP-6	1
#2	IIP-6 to IIP-8	2-3
#3	IIP-2 to IIP-8 or IIP-8 to IIP-13	3-4
#4	IIP-6 to IIP-13	5-7
#5	IIP-2 to IIP-13	6-8

*A "hybrid" turnaround is one in which only part of the space vehicle is recycled while all other sections remain in a hold condition.

**This item was resolved by the "wet" CDDT when it was found that the conoseals did not have to be retorqued after LV exposure to cryogenics. Douglas, however, will probably continue checking the conoseals on future vehicles following each CDDT to determine if retorquing is necessary.

***The time available, as shown, will vary depending on the time of year (see Figure 7).

The differences from C' in hold capability and/or turnaround requirements for an F or G vehicle is due to LM operations. The "complete" vehicle turnaround curve for F or G is shown in Figure 4 including "minimum" launch slippage. Figure 6 shows launch slippage by hold or turnaround for a scrub at any T-time against daily launch windows in a 1969, launch opportunity. Hybrid turnarounds are not shown.

1. Hybrid Turnarounds, F and G Missions

A hybrid or "partial" vehicle turnaround (one or two-day launch slip) is possible--similar to that previously described for C'--depending on the T-time of scrub.

a. One-Day Turnaround from Scrub Prior to LV Cryo Load (Case #1 Lunar)

If a scrub is declared before LV cryo tanking begins (T-8 hours), the launch can be slipped one day through the following:

1. return the MSS to the pad
2. extend MSS Platform #3
3. reservice LM-SHe
4. remove the MSS
5. launch countdown (9 hours).

The above operations would take approximately 32 hours in real time. This conforms with the allowable time frame for a one-day slip (8 hours of unused countdown plus 24 hours between T-0's). It is assumed that the CSM remains in a holding condition, that no serial repair time is involved, and that flight crew turnaround can be accomplished in the same time frame.

b. One-Day Turnaround from Scrub after LV Cryo Load (Case #1 Lunar)

A one-day launch slip from a scrub after LV cryogenics are loaded is presently constrained by:

1. Flight Crew Turnaround

The flight crew recently stated they could support a 24-hour launch slip from a scrub near T-0, but for the C' mission only. It is anticipated that crew turnaround for

subsequent lunar missions may be longer than 24 hours, particularly for a G mission. The constraint evolves from a timeline of activities encompassing crew egress, desuiting, mission briefing, simulator time, on-board data package, etc., including meals, rest, and countdown.*

2. LM-SHe

The LM-SHe must be reserviced during turnaround operations (actually, any time a scrub is declared after T-17 hours).** This reservicing requires more time than is available from a scrub after LV cryogenics are loaded until a T-0 on the following day.

c. Two-Day Turnaround from Scrub after LV Cryo Load (Case #2 Lunar)

A two-day launch slip from a scrub after LV cryo load is constrained by a requirement to reservice CSM and LM cryogenics. As shown in Figure 4, the minimum turnaround time required for a complete backout (detank LV cryos), reservice the spacecraft and countdown is approximately 65 hours. This obviously entails a three-day launch slip. Since LM-SHe reservicing is necessary in any case, the launch slip might be reduced to two days by (1) detanking the LV, and (2) reservicing only the LM-SHe (same as the operations listed for a one-day "partial" turnaround).*** This assumes that other turnaround operations such as APS Gas Removal, PU Calibrations, F-1 Engine Drain, LV Flight Battery Replacement, etc., can be accomplished within a time frame of 44 to 56 hours depending on the time of scrub. It should be noted that while holding the CSM for two days, consumption of on-board CSM cryos may seriously deplete reserves normally available for the mission.

d. Two-Day Turnaround from Scrub Prior to LV Cryo (Case #2 Lunar)

For scrubs at T-8 hours or earlier in the countdown, F or G vehicles can undergo a complete turnaround and support a two-day launch slip (shown in Figure 6).

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*In order to support a 24-hour turnaround for C', the flight crew would have deleted the simulator activities.

**Reference 8

***Reference 2

e. Effects of Unused Built-in Hold Time

A standard feature of Apollo/Saturn V countdown has been a 6-hour built-in hold scheduled at T-9 hours.* There is a fair probability, based on previous launches, that some or perhaps all of the available hold time will not be used to correct prior anomalies. In the event a scrub is declared before T-9 hours, the launch slippage curves in Figures 3 and 6 will be affected by the amount of unused hold time (Figure 8) where the launch slippage curve is proportionately moved to the right depending on the slope of the curve and the amount of unused built-in hold.

f. Available Contingency Time for Repair/Replacement

A basic assumption in establishing a minimum vehicle turnaround time is that any repairs can be accomplished in parallel with the turnaround or holding operations. However, the possibility of serial repair time does exist. From an examination of Figures 3 and 6, it can be seen that at most T-times (of scrub), there is additional time between the launch slippage curve and the next available launch window. The amount of time available for serial repair is therefore a function of turnaround requirements and the time between launch windows. This can be easily converted into a graph of each case # lunar-turnaround for use as a handy reference. An example is shown in Figure 9 (assuming a G mission vehicle and a Case #3 lunar launch slip).

IV OTHER CONSIDERATIONS

There are several considerations in scrub-turnaround operations which KSC has recognized as needing further definition.

a. Scrub after "Forward Service Arm Retract" at T-16.2 Seconds

Scrub-turnaround planning has always considered the "worst case" as a scrub at Engine Ignition Command (T-8.9 seconds). Reference 7 discussed vehicle recycle capability after retraction of the Forward Service Arm (Swing Arm #2). It was shown that after the arm is retracted, the vehicle is committed to either launch or scrub. The reason, briefly, is that following the start of S-II stage J-2 engine chill-down at T-8 minutes the temperature of the S-IC forward

*Additional built-in hold time was added to the C' countdown. While it has not been definitely decided to do the same for F or G countdowns, the comments in this section still apply.

skirt thermal environment begins dropping. To keep the temperature from dropping below red-line limits of the electronic canisters in the S-IC forward skirt, hot GN_2 is introduced into the S-IC/S-II interstage area at rates up to 500 lbs/min. This hot GN_2 is supplied through lines running over Swing Arm #2. After Swing Arm #2 is retracted, it can only be reconnected manually. In order to provide safe access for manual reconnect, the LV cryogenics must be detanked--a period of 4-plus hours. Thermal red-lines, therefore, would soon be exceeded in the event of a hold after the arm is retracted. Since Swing Arm #2 has never been retracted except during an actual launch (there have been no holds to date after SA #2 retract), the effects of a prolonged cold soak on the S-IC forward canisters is not known, including any replacement/retest which may be required during turnaround operations. One possible suggestion is that MSFC might establish some criteria by acquiring data through a special test at KSC.

b. Scrub after F-1 Engine Ignition

Turnaround time from a scrub F-1 engine ignition is not precisely known--there are related areas that cannot be predicted which could preclude meeting a launch window before close of a lunar launch opportunity. Recognizing this, however, KSC is compiling all available information on the subject to be in the best possible posture in case of a scrub after F-1 engine ignition.

V. SUMMARY

a. The basic configuration (i.e., LM) difference between C' and F or G vehicle does not increase the time required for a complete vehicle turnaround after LV cryo load.

b. Assuming a hybrid turnaround, an F or G launch can be slipped one day following a scrub at or prior to T-8 hours providing no serial repair time is involved.

c. A one-day launch slip after LV cryo load (or from any T-time after T-8 hours) for an F or G vehicle is presently constrained by:

1. LM-SHe reservicing requirements

2. Flight crew turnaround.

d. Assuming a complete F or G vehicle turnaround, the launch will slip:

1. A minimum of one day for a scrub at or prior to T-22 hours.

2. A minimum of two days for a scrub at or prior to T-9 hours.

3. A minimum of three days for a scrub after T-9 hours.

2032-CHE-mp

C. H. Eley III

Attachments
Figures 1-8

References

1. "Apollo/Saturn V Space Vehicle Scrub-Turnaround Plan (Apollo 8) SA-503/CSM 103," KSC document dated December 2, 1968

2. AS-504/Lunar Vehicle Scrub-Turnaround Bar Charts (Preliminary) dated December 27, 1968

3. "Apollo/Saturn V Launch Mission Rules - Apollo 8 (SA-503/SM-103)"

4. Manned Apollo/Saturn V Countdown Working Group Meeting Notes - June through December, 1968

5. AS-504/Lunar SV Countdown Test Processing Chart dated January 9, 1969

6. AS-503 SV Countdown Test Processing Bar Chart dated December 6, 1968

7. "Saturn V Hold Limitations and Short Recycle Requirements During Terminal Countdown," Case 320, Bellcomm TM-67-2032-4, dated December 15, 1967 by C. H. Eley III

8. "Operational Constraints and Requirements Associated with a 44-hour Turnaround Capability for the Apollo/Saturn V," Case 320, Bellcomm Memorandum for File dated June 28, 1968, by G. W. Craft, D. M. Duty, C. H. Eley III, and G. J. McPherson Jr.

BELLCOMM, INC.

Subject: Comparison of Apollo/Saturn V Scrub Turnaround Capabilities for C', F and G Missions - Case 320

From: C. H. Eley III

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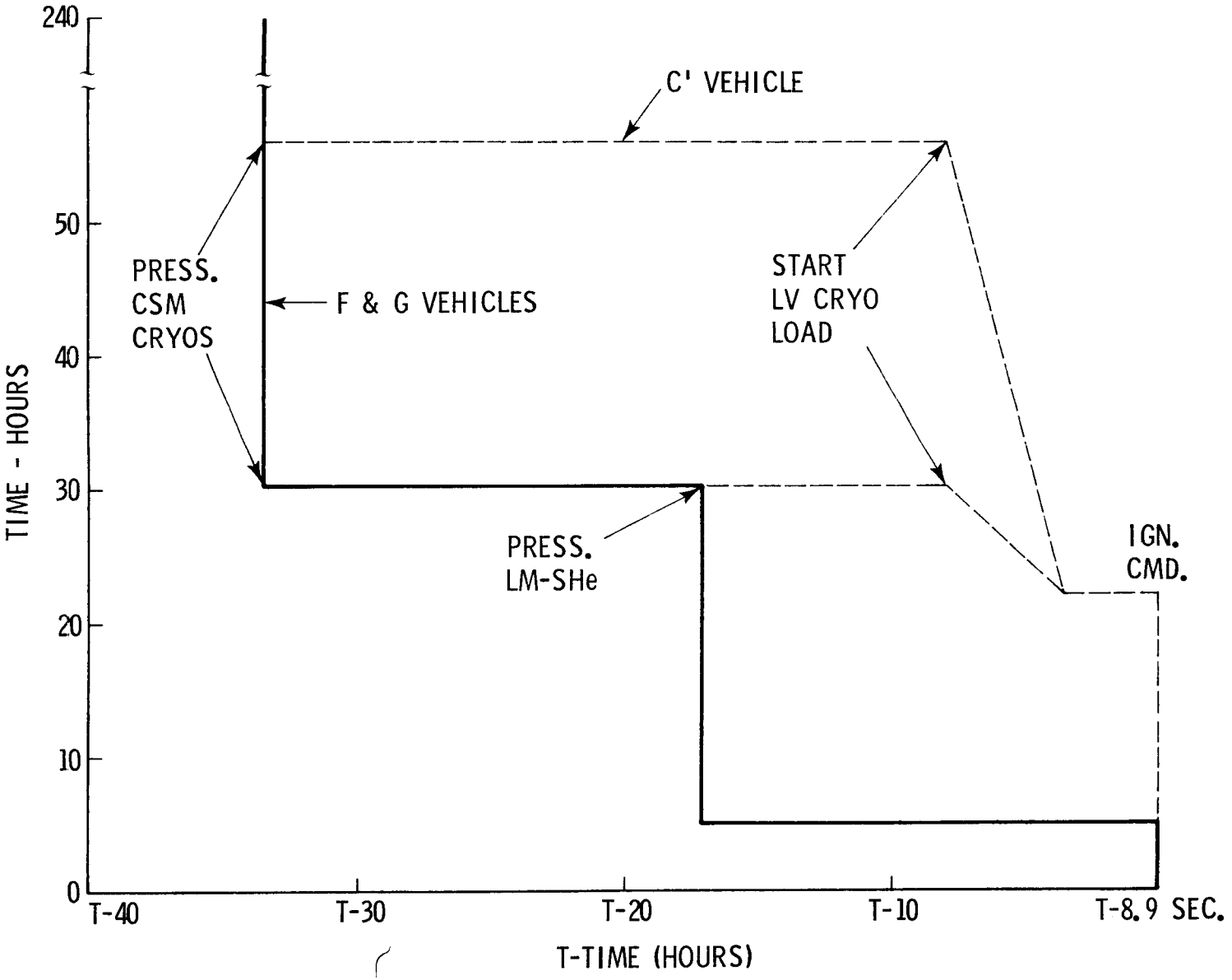


FIGURE 1 - APOLLO/SATURN V HOLD CAPABILITIES

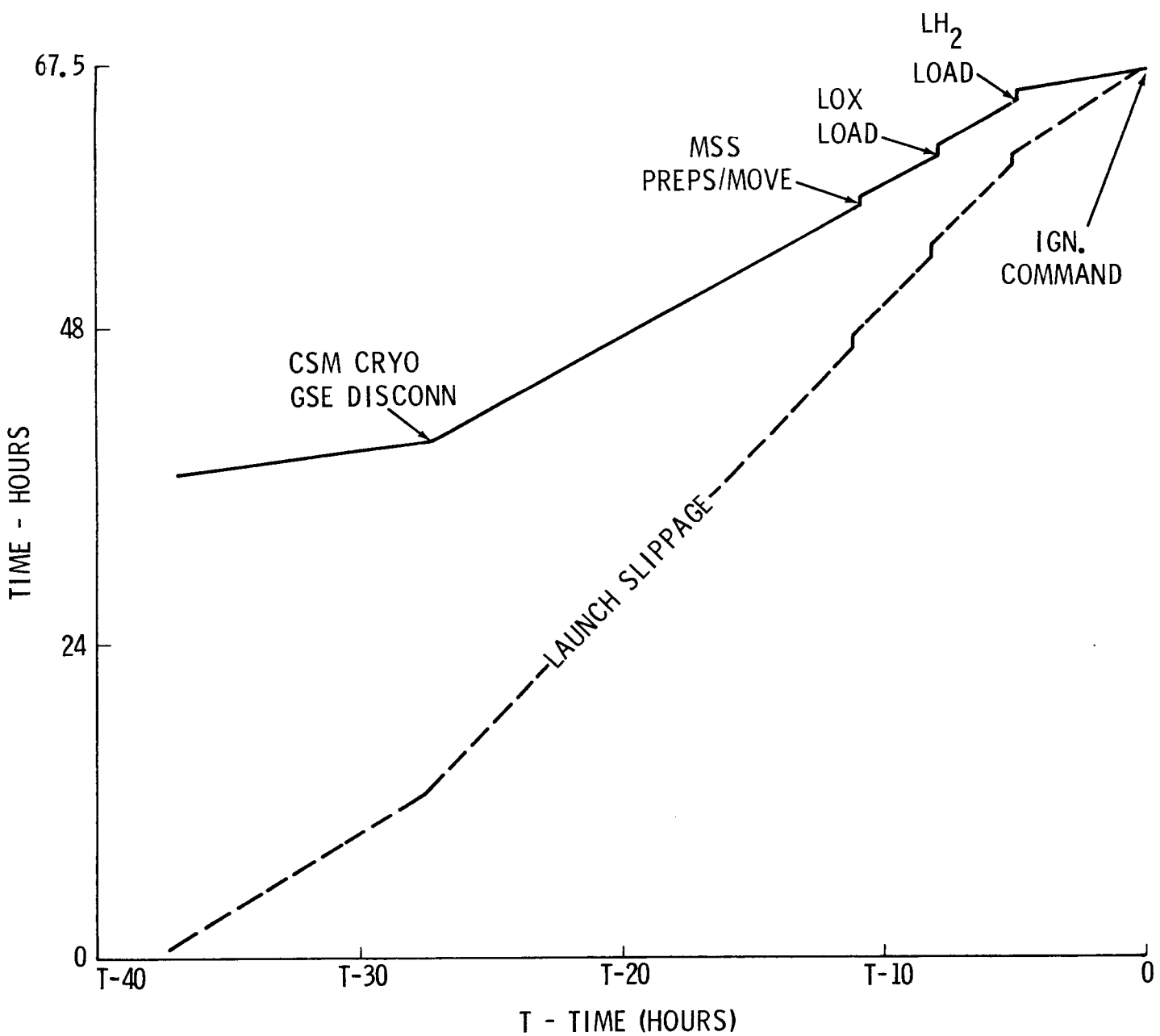


FIGURE 2 - AS-503/CSM-103 VEHICLE TURNAROUND TIME vs. T-TIME OF SCRUB

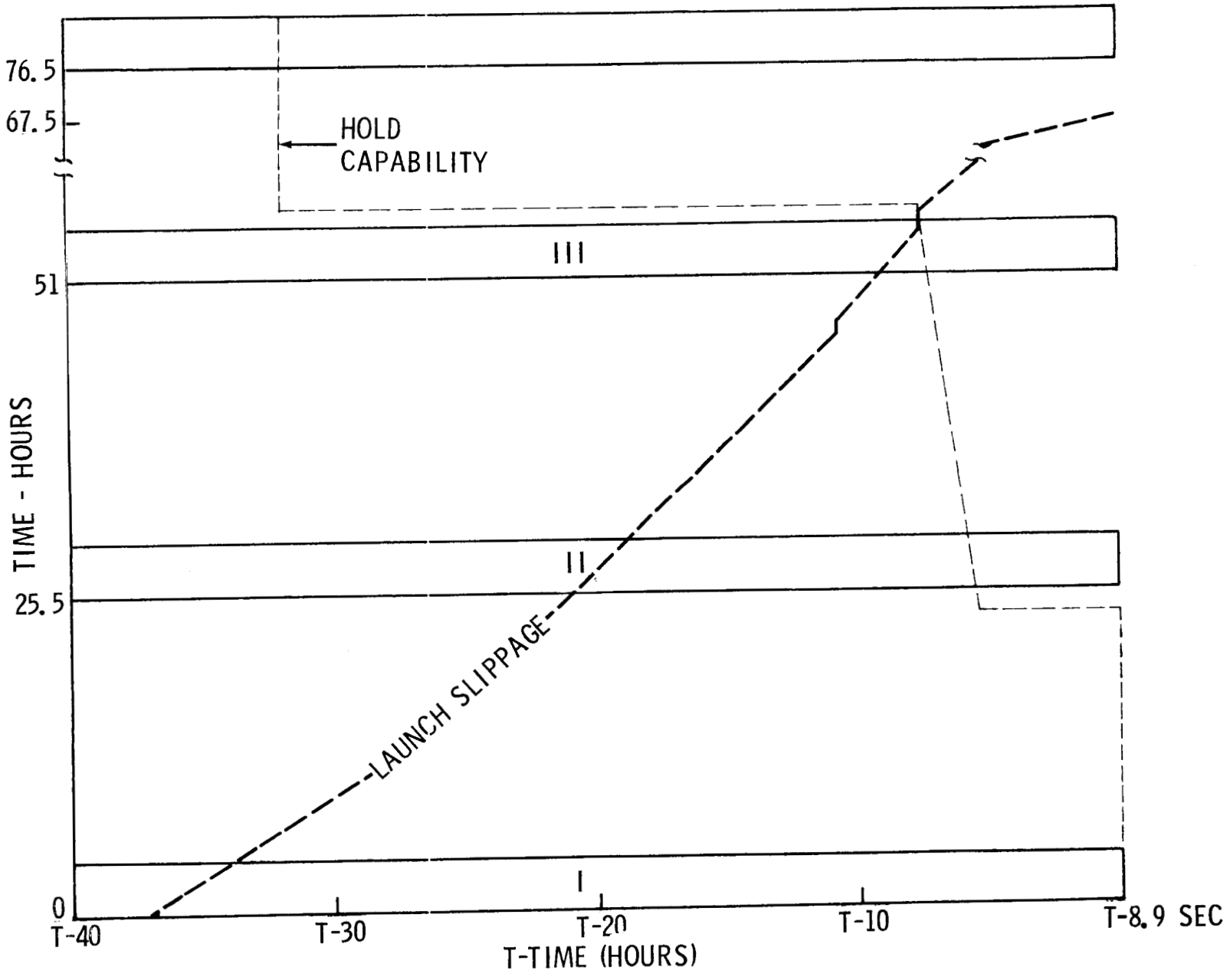


FIGURE 3 - C' LAUNCH WINDOW SLIPPAGE vs. T-TIME OF SCRUB FOR DECEMBER, 1968 LAUNCH WINDOWS

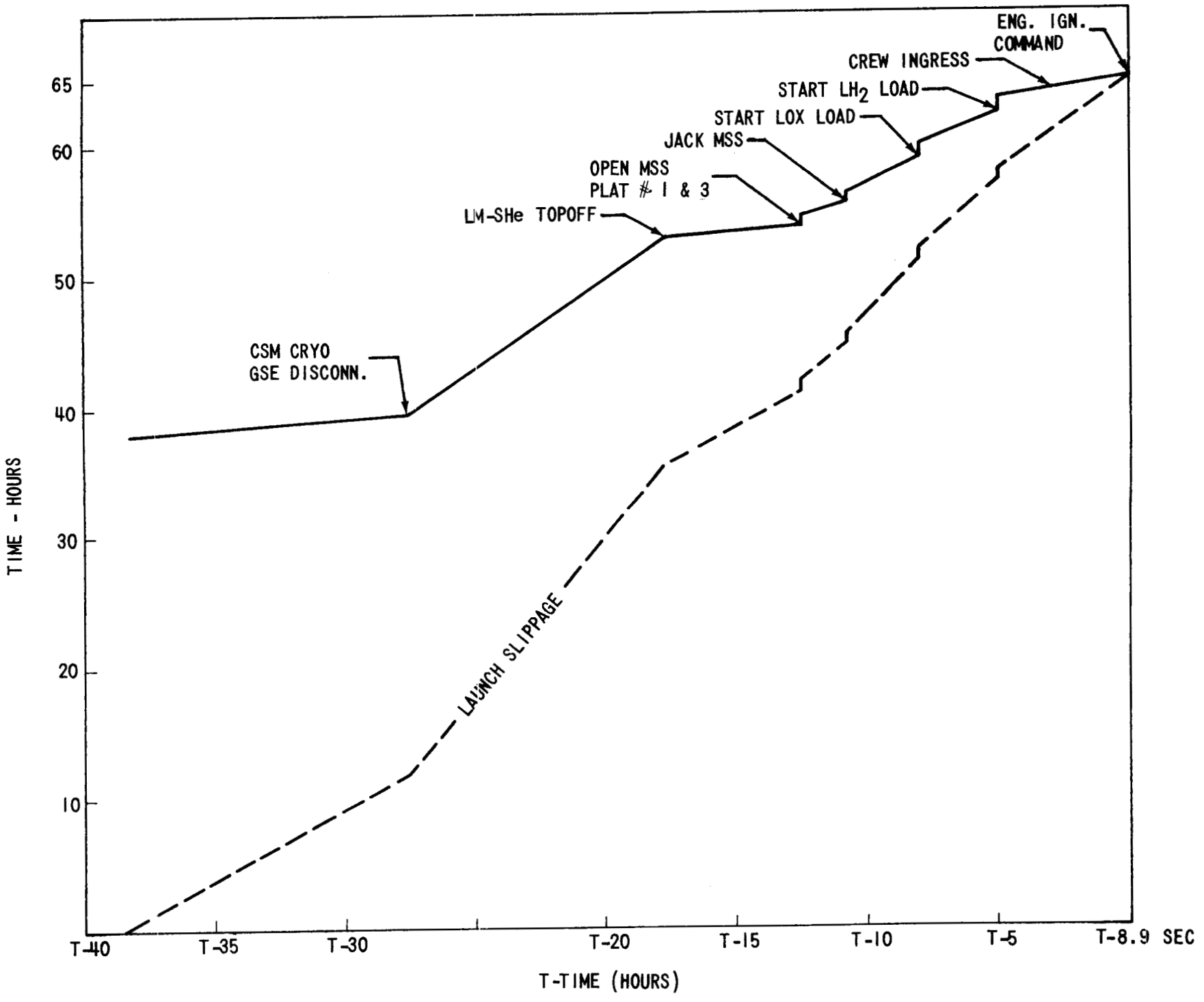
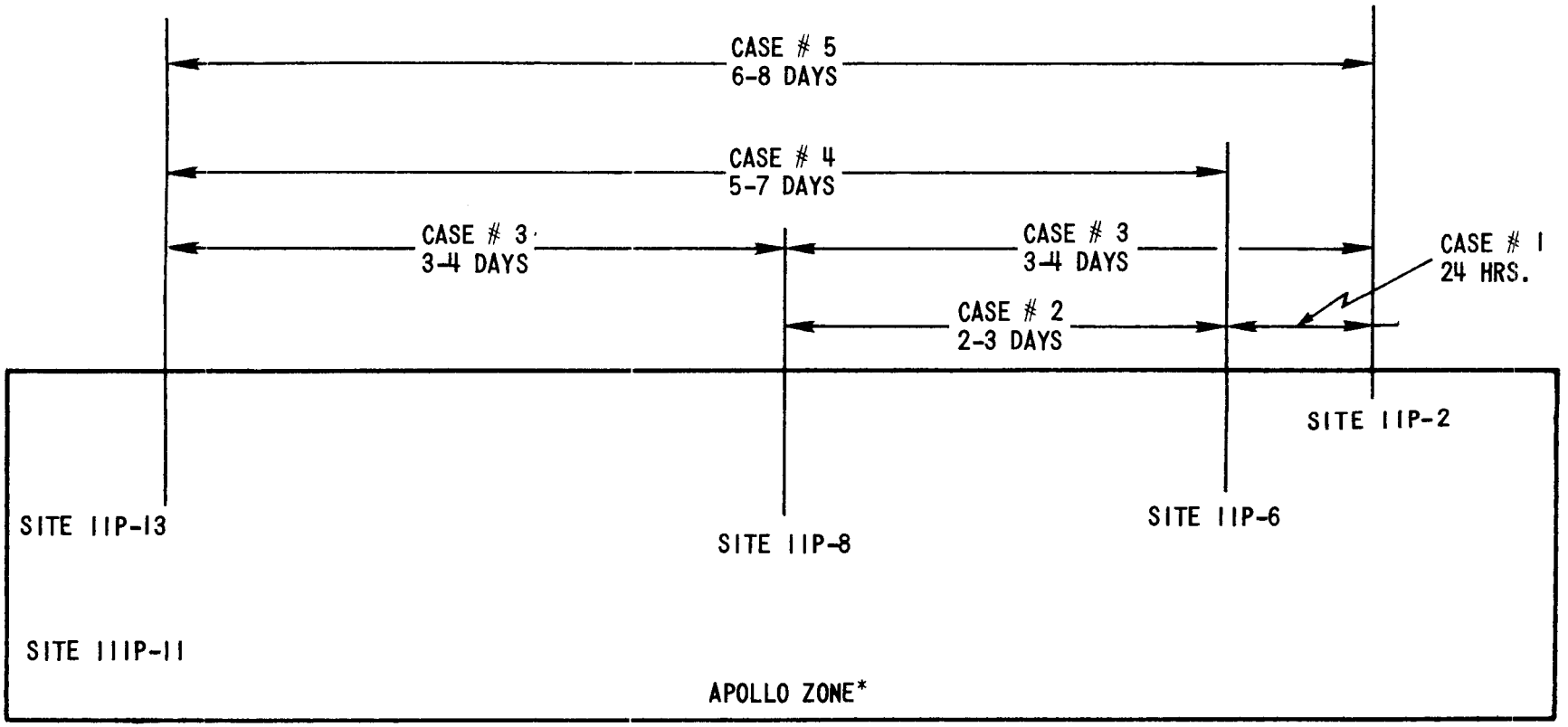


FIGURE 4 - F & G TURNAROUND TIME vs. T-TIME OF SCRUB



*NOTE: SITE AVAILABILITY MOVES FROM RIGHT (EAST) TO LEFT (WEST) AFTER START OF OPPORTUNITY.

FIGURE 5 - TYPES OF SCRUB-TURNAROUNDS FOR F & G LUNAR LAUNCH OPPORTUNITIES IN 1969

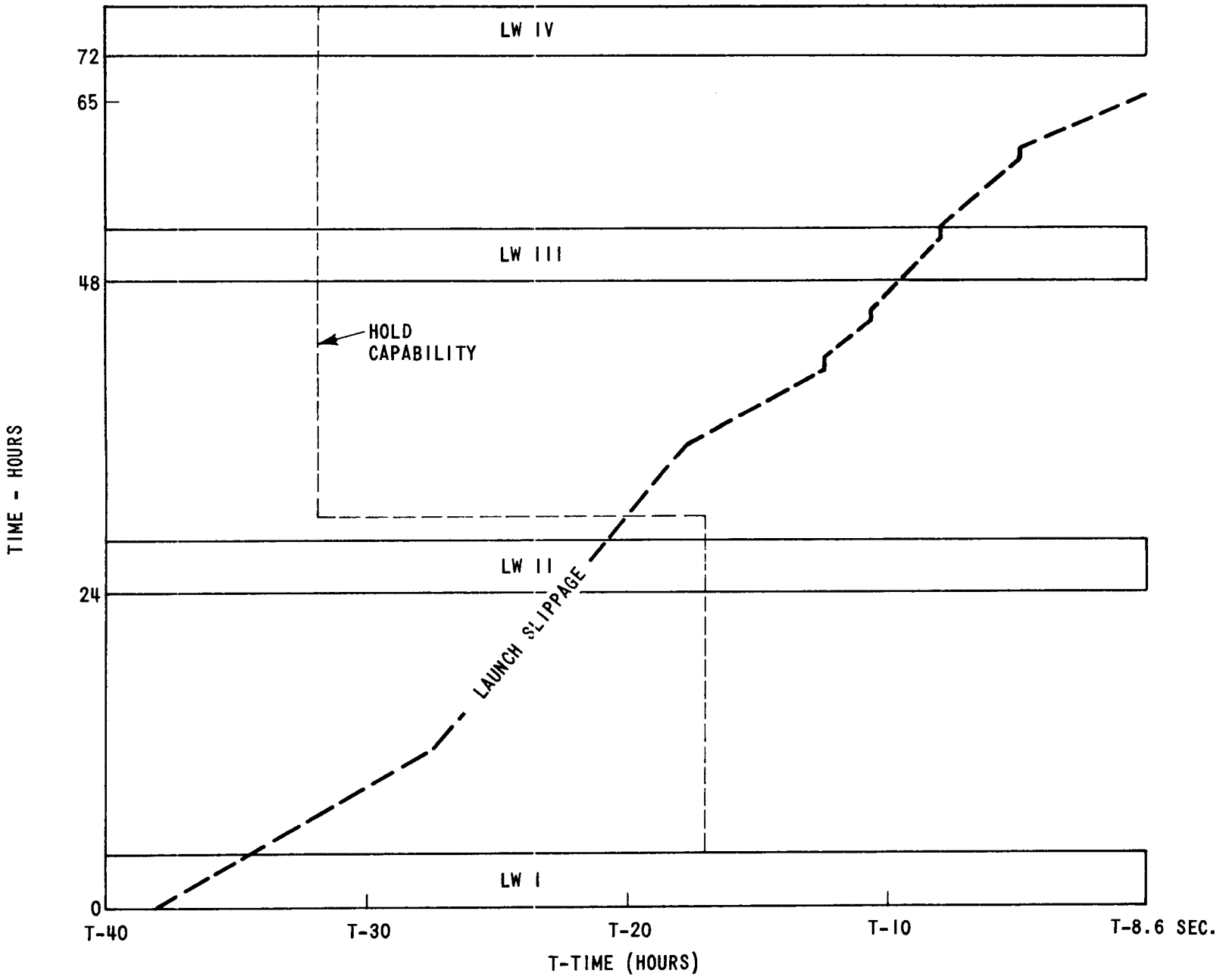


FIGURE 6 - F & G VEHICLE LAUNCH WINDOW SLIPPAGE vs. T-TIME OF SCRUB

LUNAR LAUNCH DATES - 1969

(BASED ON CURRENT LUNAR LANDING SITES,
LIGHTING CONSTRAINT AND TRAJECTORY PROFILE)

CALENDAR DATES	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
JANUARY																			N	N		N			N						
FEBRUARY																	D	D			D			D							
MARCH																			D	D		D			D						
APRIL																		D	D		D			D							
MAY																	D	D		D			D								
JUNE																D	D		D			D									
JULY															D	D		D				D									
AUGUST													N	N			N					N									
SEPTEMBER												N	N			N			N												
OCTOBER											N	N		N					N												
NOVEMBER										N	N			N			N														
DECEMBER										N	N		N			N															

NOTE:
D - DAY LAUNCH (PACIFIC)
N - NIGHT LAUNCH (ATLANTIC)
DATES ARE REFERENCED TO
A 72^{0} LAUNCH AZIMUTH (EST)

FIGURE 7

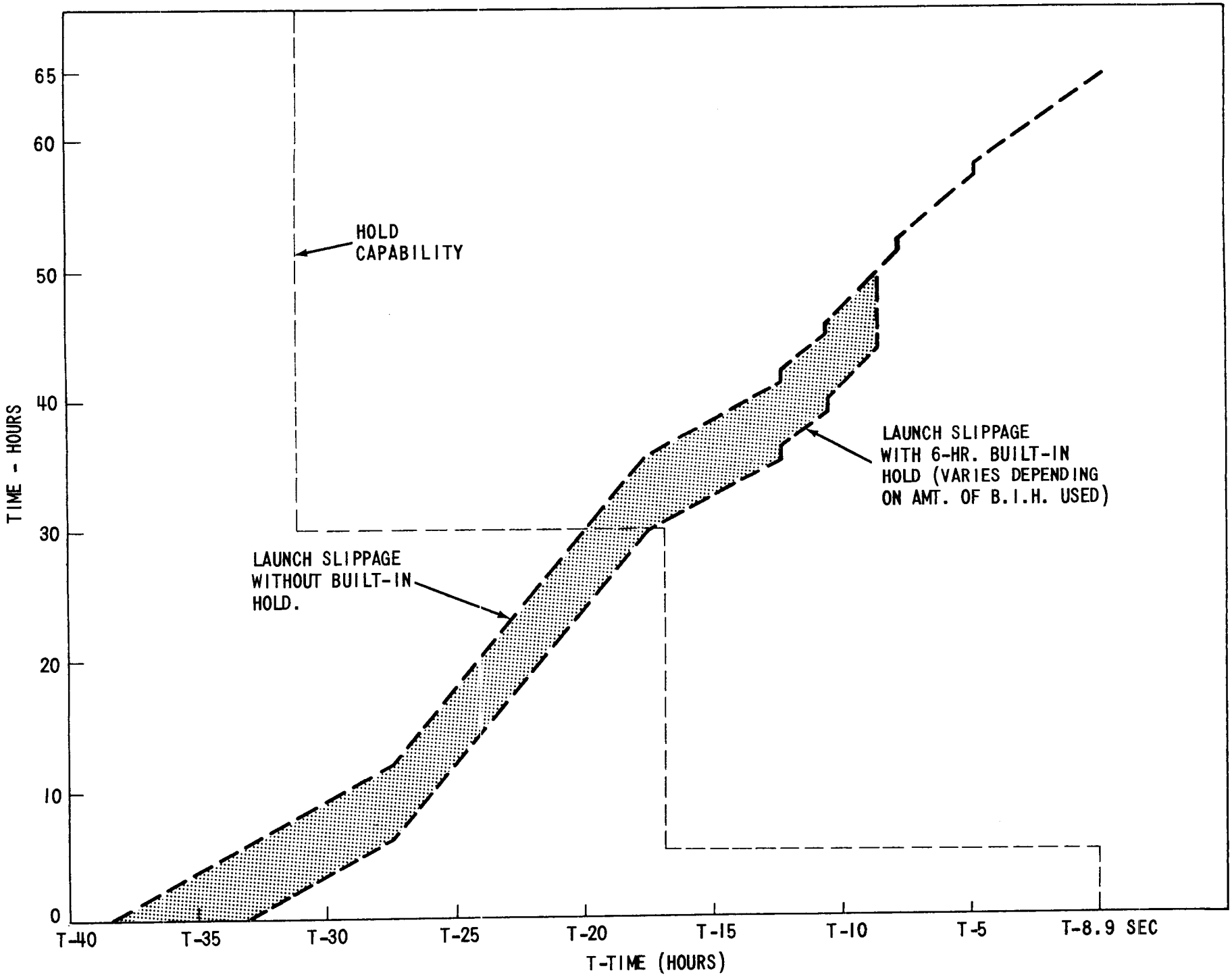


FIGURE 8 - LAUNCH SLIPPAGE vs. T-TIME OF SCRUB (LUNAR VEHICLE)

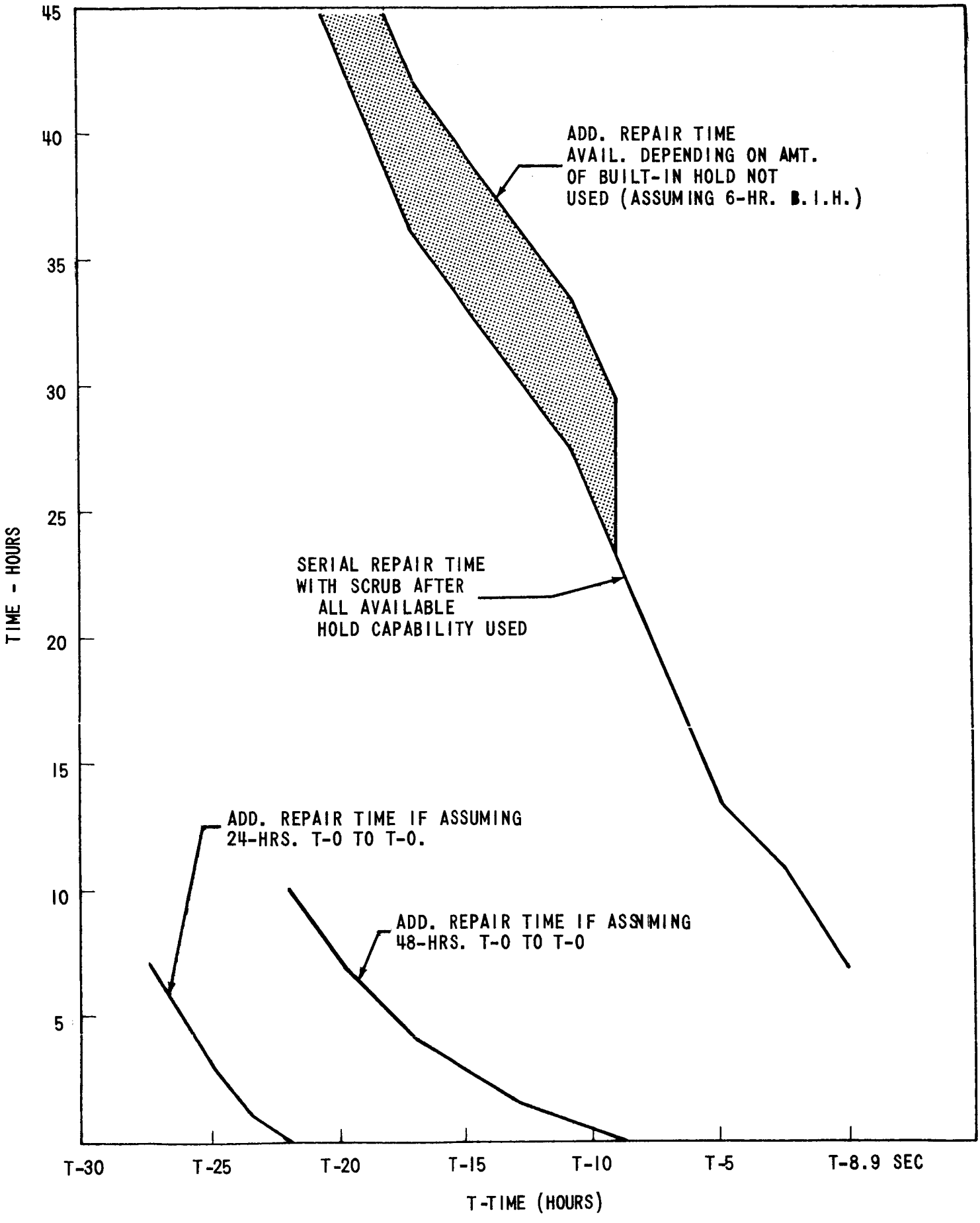


FIGURE 9 - SERIAL REPAIR TIME AVAILABLE vs. T-TIME OF SCRUB (ASSUMING 72 HRS. T-0 TO T-0) FOR F & G VEHICLES